DARPA Focus 2000

Computing in the Bio-Substrate

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Computing in the Bio-Substrate

- **Custom control circuits in living cells**
  - **Switches and switching networks**
  - **Biosensors and biocontrol circuits**
  - **Design methodologies**
  - **Robustness and reliability**
  - **Simulation tools and methodologies**
- **Hybrid bio-electronic circuits and sensors**
  - **Cells on chips**
  - **Electronic I/O to biological substrates**
- **Self-assembly**
  - **Ordered nano-structures**
  - **DNA computation**

Opportunities

Microbiological bio-sensors

- Capable of sensing external biological molecules and other signals
- Custom logic for modulating responses
- Conditional genetic response
- Real-time or delayed read-out
- Integrated biological/silicon sensors (biomicroelectronics)
- Potential for multicellular collaborative sensors

Potential new class of sensors with molecular-level specificity and sensitivity

- Lightweight deployable
- Low-cost
- Programmable

Naturally occurring Sensors and Actuators

Sensors

- Light (various colors)
- pH
- Molecules
  - autoinducers
  - H2S
  - Maltose
  - Serine
  - Ribose
  - cAMP
  - NO
- Internal State
  - Cell cycle
  - Heat shock
- Chemical & ionic potentials
- Magnetic & electric fields

Responses

- Motility
  - flagellar activity
  - gliding motion
- Light (various colors)
- Fluorescence
- Small molecule excretion
- Membrane transport
- Sporulation
- Cell cycle progression
- Exported proteins
  - enzymes/toxins
  - extracellular matrix
- Cell death

Opportunities

Innovative design and modeling tools for designing custom biological circuits and analysis of naturally occurring circuits

- **Next generation of BioSpice (mixed mode, stochastic and deterministic models, hierarchical models)**

Barrier to progress in several areas

Opportunities

Programmable, self-assembling, high-precision (± 0.5 nm) 2D and 3D periodic and aperiodic crystalline structures from branched DNA molecules with <10 nm feature sizes

- **Macromolecular crystallization for structure determination**
- **Templates for nanoelectronics**
- **Nano-manufacturing substrate**

Enabler for self assembled molecular structures needed for a next generation electronics